Wildl. Soc. Bull. 20:264-273, 1992

WILDLIFE SPECIES RICHNESS IN SHELTERBELTS: TEST OF A HABITAT MODEL

RICHARD L. SCHROEDER, *National Ecology Research Center, U.S. Fish and Wildlife Service, 4512 McMurry Avenue, Fort Collins, CO 80525-3400*

TED T. CABLE, *Department of Forestry, Call Hall, Kansas State University, Manhattan, KS 66506*

SANDRA L. HAIRE, *National Ecology Research Center, U.S. Fish and Wildlife Service, 4512 McMurry Avenue, Fort Collins, CO 80525-3400*

Shelterbelts are human-made habitats consisting of rows of shrubs and trees planted either in fields or on the windward side of farmstead dwellings. Shelterbelts provide wooded habitat for a large variety of birds and other wildlife. A model to predict wildlife species richness in shelterbelts (Schroeder 1986) was published as part of the U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) model series (Schamberger et al. 1982). HSI models have been used extensively by wildlife managers and land use planners to assess habitat quality. Several HSI models have become the focus of a test program that includes analysis of field data for corroboration, refutation, or modification of model hypotheses. Previous tests of HSI models focused either on single species (e.g., Cook and Irwin 1985, Morton et al. 1989, Schroeder 1990) or examined portions of HSI models, such as the relationship between cavity abundance and tree diameter (Allen and Corn 1990). The shelterbelt model, however, assesses habitat value at the community level. The effects of habitat characteristics, area, and perimeter on diversity and abundance of bird and mammal species in shelterbelts were first studied by Yahner (1983*a,b*). Johnson and Beck (1988) confirmed the importance of shelterbelts to wildlife and identified area, perimeter, and diversity and complexity of vegetation as key measurements of habitat quality. The shelterbelt model incorporates both specific habitat variables and larger scale parameters, such as area and configuration, to predict wildlife species richness. This shift in perspective comes at a time of increasing interest in conservation and planning beyond the species level (e.g., Graul and Miller 1984, Hutto et al. 1987, Schroeder 1987: 26).

We report results of a 3-year study of spatial and vegetative parameters and their relationship to breeding bird species richness (BSR) in 34 Kansas shelterbelts. Our objectives were to test the hypothesis presented in the original shelterbelt model (Schroeder 1986) that species richness can be predicted by shelterbelt characteristics and to investigate alternative models for predicting BSR in shelterbelts.

STUDY AREA AND METHODS

The study area was in northern Stafford and eastern Pawnee counties, south-central Kansas, in the Great Bend Prairie physiographic subprovince of the Great Plains. This area is characterized by an undulating plain of slight relief, with large, nearly level areas. The land use was dominated by irrigated agricultural lands, and wheat, grain sorghum, and alfalfa were the major crops. Soils were generally sandy, and low, rolling dunes occurred in some areas. This study area was chosen because it included both large, old shelterbelts that were planted in the 1930's as part of the Prairie States Forestry Project and younger, smaller shelterbelts.

The sample consisted of 34 shelterbelts exhibiting variation in shelterbelt characteristics included in the HSI model. The selected shelterbelts ranged from 0.03–11.66 ha in area and from 66–3,267 m in length. Twenty-one species of trees and shrubs were identified in the shelterbelts. The most frequently occurring species was eastern juniper (*Juniperus virginiana*), which occurred in 85% of the shelterbelts. Other common species were eastern cottonwood (*Populus deltoides*) (50%), osage-orange (*Maclura pomifera*) (47%), Siberian elm (*Ulmus pumila*) (41%), and black locust (*Robinia pseudoacacia*) (41%).

We attempted to obtain a complete count of the total number of breeding bird species in each shelterbelt during a 3-year period. Censuses were conducted for 3 consecutive years (1988–1990) between 23 May and 16 June. These dates were chosen to minimize numbers of migrant species and yet allow the fieldwork to be completed while the birds were actively singing. Birds in the shelterbelts during this period were considered to be nesting unless the breeding range did not include central Kansas. Each shelterbelt was visited on 1 day each year. Birds were censused by recording all birds seen or heard while walking the length of the shelterbelts. Shelterbelts <5 rows wide were walked twice, once through the center and once on the side leeward to the wind direction at the time of the censusing. Shelterbelts of ≥5 rows were walked 3 times, along each outside edge and once through the center. Therefore, for the entire study, shelterbelts <5 rows were walked 6 times, and those with ≥5 rows were walked 9 times. Because our primary objective was to observe all species present, a tape recording of the vocalizations of the eastern screech-owl (*Otus asio*) was played on the final pass through the shelterbelt each year. This method was employed to detect both screech-owls and passerine species that otherwise might have gone unnoticed. Because of narrow shelterbelt widths and general lack of adjacent cover, we assumed that virtually all the avian species would be seen or heard. All censuses were initiated between sunrise and 1100 hours. All observed species were recorded, and the number of individuals was estimated. BSR for each shelterbelt was computed as the cumulative number of breeding bird species recorded during the entire study.

We collected data describing the 6 variables in the shelterbelt model (Fig. 1) using techniques described in Schroeder (1986). Specifically, shelterbelt configuration, number of rows, and number of woody plant species contributing ≥1% of the canopy closure were determined by visual inspection. The area of each shelterbelt was calculated from direct field measurements of length and width. Tree heights were measured with a Blume-Leiss altimeter. Percent canopy closure was estimated by a line-intercept sampling technique, with lines oriented at randomly selected angles across the rows of the shelterbelt. Mean shelterbelt height and mean canopy closure were estimated using a sufficient number of randomly selected data points for a 90% confidence of an estimate within 10% of the true mean (Snedecor and Cochran 1967:58–59). We calculated HSI values for each of the 34 shelterbelts. We also collected data to describe foliage height diversity (FHD) (MacArthur and MacArthur 1961), adjacent land use, density of snags or large (>20 cm diameter) dead branches, evidence of grazing, and distances to farmsteads and other wooded tracts. Simple and multiple linear regression methods were used to relate habitat variables to BSR, and significance was defined as $P \leq 0.05$. Habitat and spatial variables for shelterbelts with bird species categorized as forest interior or area sensitive (hairy woodpecker [*Picoides villosus*], tufted titmouse [*Parus bicolor*], and red-eyed vireo [*Vireo olivaceus*][Temple 1986]; eastern wood-pewee [*Contopus* *virens*] [Small and Hunter 1989]; and white-breasted nuthatch [*Sitta carolinensis*] [Blake and Karr 1984]) were compared with shelterbelts lacking such species using multiresponse permutation procedures (MRPP) (Biondini et al. 1988). The MRPP test statistic is based on average Euclidean distances within groups; consequently, this is the descriptive measure of dispersion reported.

RESULTS

A total of 62 breeding bird species (Appendix) was observed on the 34 shelterbelts during the 3-year study. BSR ranged from 7 (0.03-ha shelterbelt) to 47 (10.4-ha shelterbelt) among shelterbelts and was highly correlated with the logarithm of shelterbelt area ($r = 0.85$, $P < 0.001$). Regression of BSR from the 34 shelterbelts on the HSI calculated for each belt (Fig. 2) yielded the following ($R^2 = 0.822$, $P < 0.001$) predictive equation:

$$\mathrm{BSR} = 6.84 + 36.76\ (\mathrm{HSI}).$$

Data on adjacent land use showed rangeland, wheat, oats, corn, alfalfa, stubble, and plowed ground were present in areas surrounding the shelterbelts. No relationships existed between the percent of adjacent land in any particular cover types and BSR. Distance to nearest other wooded tract (including other shelterbelts or natural woody vegetation) ranged from 0.03 to ~3.2 km, and 26 of the 34 belts were within 0.4 km of other wooded tracts. Shelterbelt isolation had no relationship to BSR. Distance to nearest farmstead did not correlate with BSR.

Number of shelterbelt rows and shelterbelt configuration (arrangement of shrub and tree rows) were difficult to measure in older shelterbelts where individual rows were often indistinguishable because of woody understory development. Narrow shelterbelts did not have readily definable boundaries; thus, measurement of tree canopy closure was impractical in many instances. Vegetation structure was associated with BSR (correlation between FHD and BSR, $r = 0.75$, $P < 0.001$). Cavity-nesting bird species ($n = 15$) composed 24% of the overall BSR in the 34 shelterbelts, and the richness of cavity nesters was highly correlated with snag density ($r = 0.81$, $P < 0.001$). Number of tree species was correlated with shelterbelt size ($r = 0.693$, $P < 0.001$).

The 10 shelterbelts with at least 1 interior or area-sensitive bird species were significantly different ($P < 0.001$) from the remaining unused shelterbelts (Table 1). Shelterbelts with forest-interior birds were larger, taller, and wider and had higher snag density and greater FHD than those without forest-interior bird species.

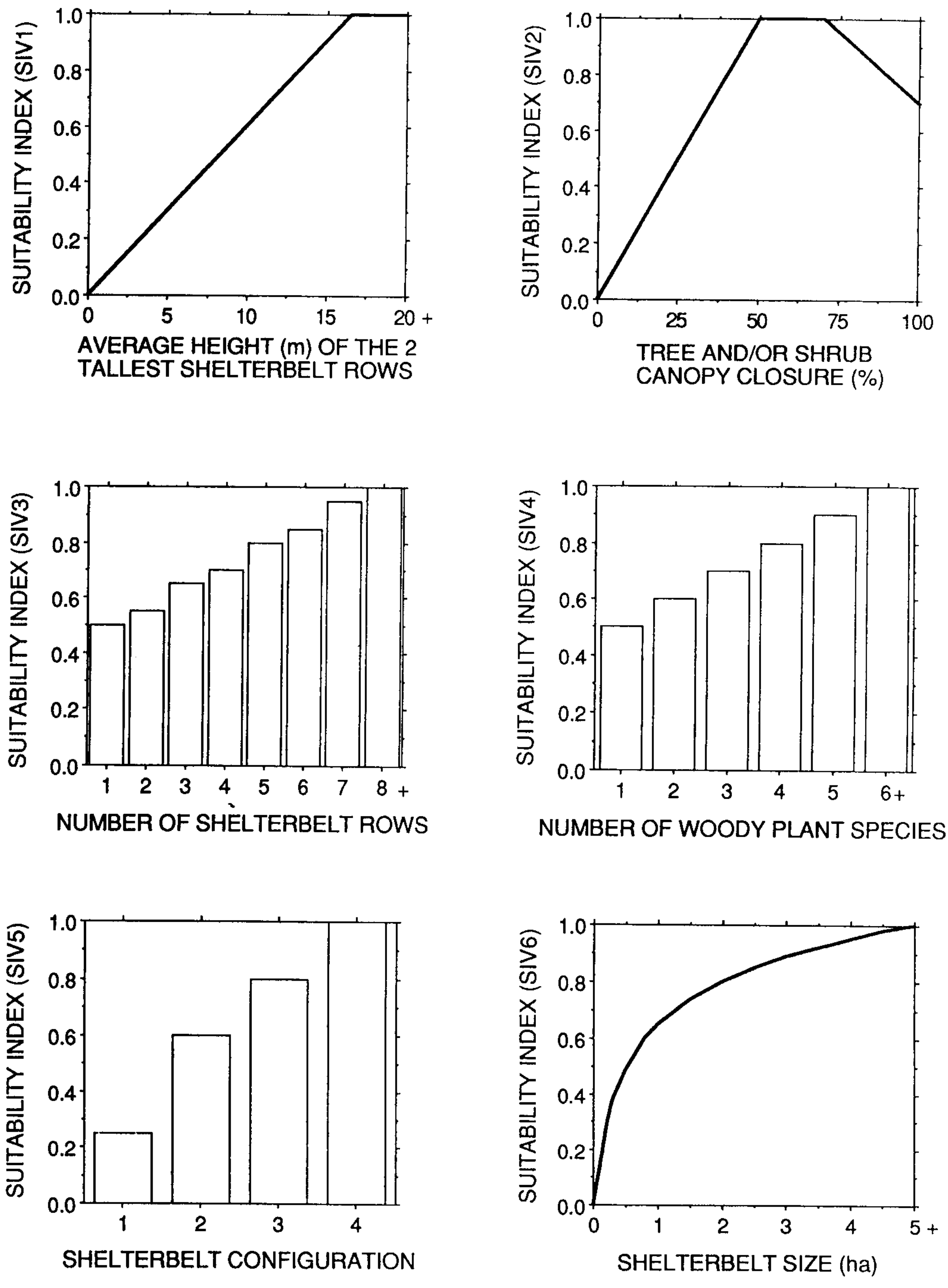
HSI MODEL MODIFICATIONS

Despite the positive correlations between BSR and HSI from the original model, the data suggested revisions of the HSI model to improve its predictive capabilities. We developed a revised model to rectify problems with field measurement of habitat variables and to add variables important in predicting BSR based on data analyses. Because of the range of values obtained for size of shelterbelt and average height of the tallest row, the revised model

→

Fig. 1. Habitat variables and Suitability Index graphs for the original shelterbelt Habitat Suitability Index model (Schroeder 1986). Legend for Suitability Index (SIV5) for shelterbelt configuration: (1) shrubs only; (2) trees only or trees on outside rows; (3) trees and shrubs, with outside shrub row(s) only on 1 side; (4) trees and shrubs, with ≥2 outside shrub rows, at least 1 on each side of the shelterbelt. Suitability Index (SIV6) for shelterbelt size computed as:

$$\mathrm{SI} = \frac{-30.514 + (4.872 \times \log_e(10{,}000 \times \mathrm{size}))}{22.19}$$


SUITABILITY INDEX (SIV1)
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20 +
AVERAGE HEIGHT (m) OF THE 2 TALLEST SHELTERBELT ROWS
SUITABILITY INDEX (SIV2)
0
25
50
75
100
TREE AND/OR SHRUB CANOPY CLOSURE (%)
SUITABILITY INDEX (SIV3)
1
2
3
4
5
6
7
8 +
NUMBER OF SHELTERBELT ROWS
SUITABILITY INDEX (SIV4)
1
2
3
4
5
6+
NUMBER OF WOODY PLANT SPECIES
SUITABILITY INDEX (SIV5)
1
2
3
4
SHELTERBELT CONFIGURATION
SUITABILITY INDEX (SIV6)
0
1
2
3
4
5 +
SHELTERBELT SIZE (ha)

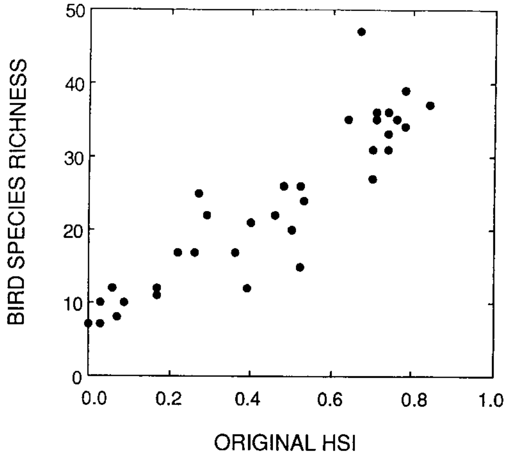


Fig. 2. Plot of breeding bird species richness, south-central Kansas, 1988–1990, versus the Habitat Suitability Index values determined from the original model (Schroeder 1986).

(Fig. 3) includes modified versions of these variables. New variables for FHD and snag density were included to reflect these habitat characteristics.

The original HSI model did not include a variable for the presence or abundance of snags. Yahner (1983/1984) suggested that snag retention was an important management consideration for shelterbelts in intensively farmed regions of the Midwest, and our data confirm the importance of snags.

The formula in the original model to estimate the Suitability Index (SI) for shelterbelt size yielded negative values for shelterbelts <0.05 ha, and such small belts were assumed to have an SI of 0.0. The original HSI model variable for shelterbelt size yielded a maximum SI at 5 ha. Because of the nature of the species-area relationship, this variable theoretically has no upper size limit for a score of 1.0. To keep the model scaled from 0–1, we suggest the size variable be revised to yield an optimum value for the largest expected belt in the region of study. We revised this variable to reflect the largest shelterbelt in our study area (11.66 ha) and to allow shelterbelts of any size >0 ha to receive a positive SI value.

Because of the difficulties described earlier in field measurement, we dropped the original model variables for percent tree or shrub canopy closure, number of rows, and shelterbelt configuration. We also did not include the variable for number of tree species in the revised model. Number of tree species was strongly correlated with shelterbelt size, and within any specific geographic area of model application we expect it to be adequately accounted for by the variable for shelterbelt size.

We added a variable for FHD as a measure of the vertical structural complexity of the vegetation. The shape of the SI graph for FHD was derived from an assessment of the effects of FHD on BSR (Fig. 4). These data indicate that FHD exerts a limiting influence on BSR. Specifically, no values for BSR are in the upper left portion of the plot, and the number of breeding birds seems to be limited by the low values for FHD within these ranges. BSR values in the lower right portion of the plotted data were not limited by BSR and may be low because of other habitat- or area-related effects. The upper limit of these plotted data points forms a logical basis for the SI graph for the revised model. Similarly, SI graphs for snag density and average height of the tallest

Table 1. Median values and dispersion of size and habitat variables for shelterbelts with and without forest-interior or area-sensitive bird species, south-central Kansas, 1988–1990.

	Size (ha)	Tree height (m)	Number of snags/ha	Foliage height diversity	Width (m)
Shelterbelts with interior bird species (n = 10)	7.0 (4.0)[a]	16.4 (4.7)	16.0 (9.8)	2.7 (0.25)	46.4 (15.1)
Shelterbelts without interior bird species (n = 24)	1.5 (1.9)	9.1 (5.4)	0.3 (7.6)	2.0 (0.47)	16.5 (14.8)

[a] Average Euclidean distance from multiresponse permutation procedure.

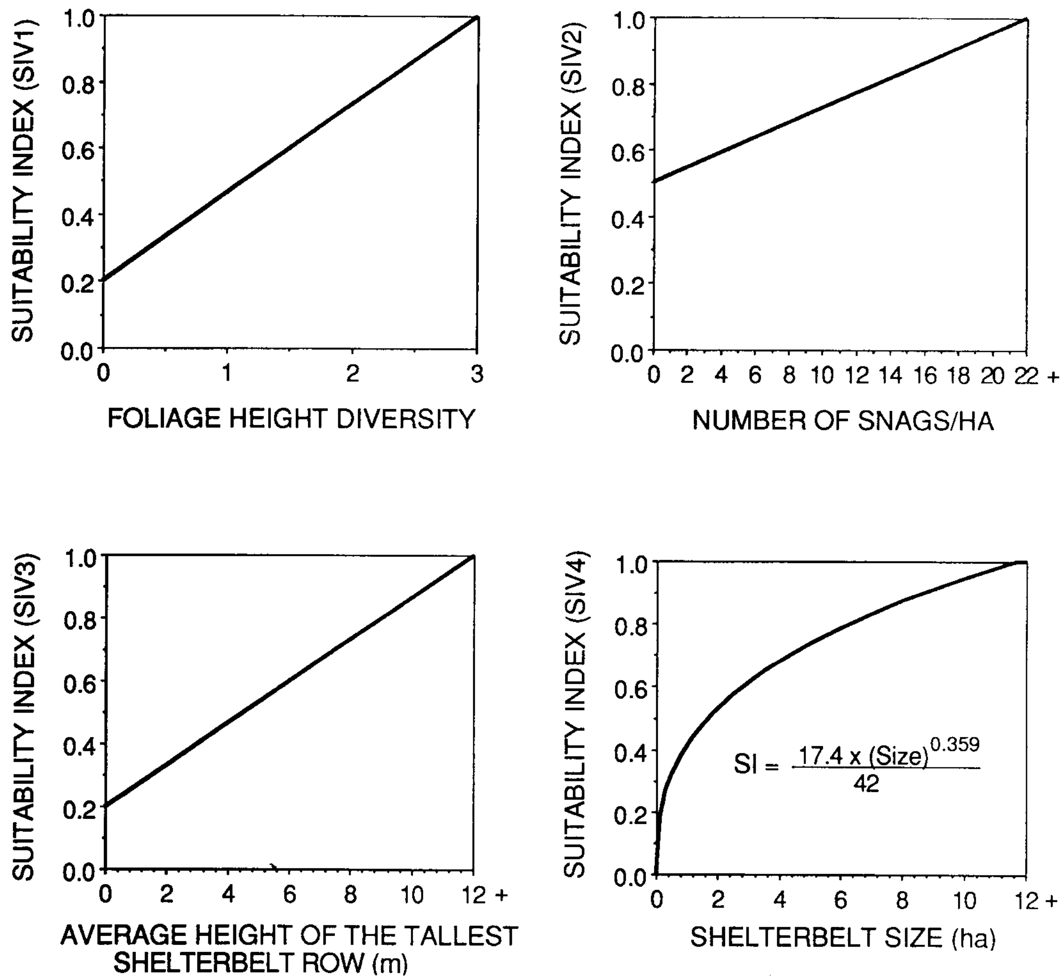


Fig. 3. Habitat variables and Suitability Index graphs for the revised shelterbelt Habitat Suitability Index model.

row were derived through assessment of upper limits of BSR determined from plotted data (Figs. 5, 6).

SI values for the revised HSI model were combined in a manner similar to that proposed in the original model, with the HSI determined as:

$$\text{HSI} = \frac{\text{FHD SI} + \text{snag SI} + \text{height SI}}{3} \times \text{size SI.}$$

Regression of BSR on the revised HSI for the 34 shelterbelts (Fig. 7) yielded a highly significant ($R^2 = 0.893$, $P < 0.001$) result:

$$\text{BSR} = 5.34 + 41.1 \text{ (revised HSI).}$$

The constant in this regression equation differed from 0.0 ($P < 0.001$). The implication is that a shelterbelt with no suitability (HSI = 0.0) would be expected to have 5.34 breeding bird species. In the revised model, however, a shelterbelt cannot actually receive a 0.0 HSI value. The SI values for the 3 habitat variables are always >0, even in worst-case conditions, and a shelterbelt of any area will receive an

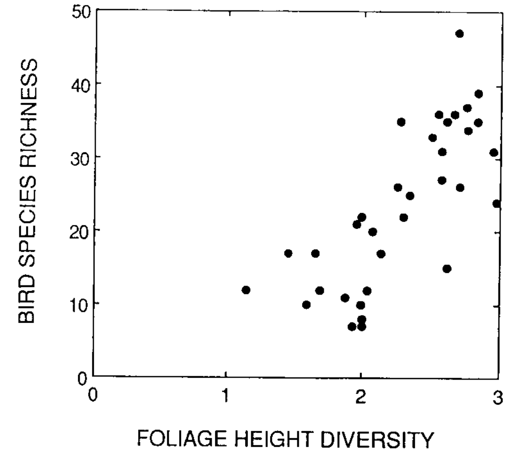


Fig. 4. Plot of breeding bird species richness versus foliage height diversity, south-central Kansas, 1988–1990.

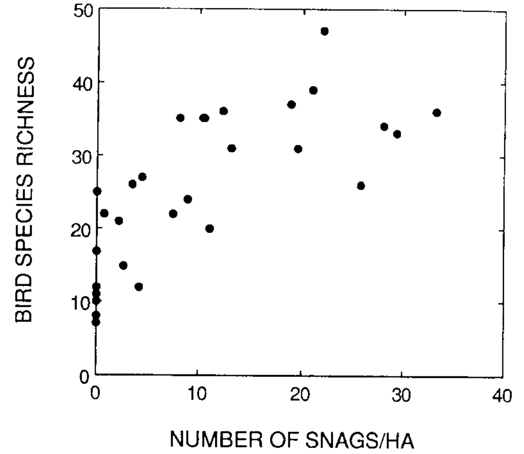


Fig. 5. Plot of breeding bird species richness versus snag density, south-central Kansas, 1988–1990.

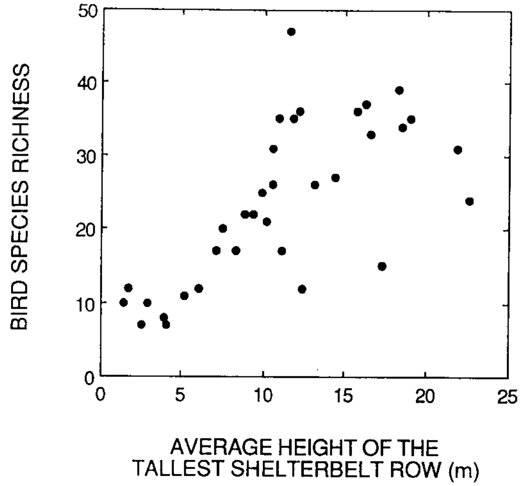


Fig. 6. Plot of breeding bird species richness versus shelterbelt height, south-central Kansas, 1988–1990.

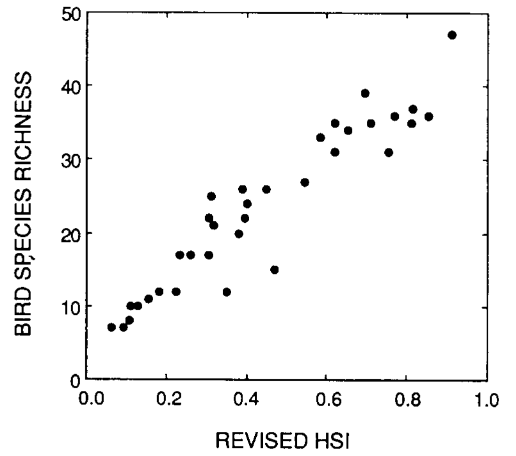


Fig. 7. Plot of breeding bird species richness, south-central Kansas, 1988–1990 versus the HSI values determined from the revised model.

HSI >0. The smallest shelterbelt in our study was 0.032 ha and had 7 breeding bird species. We expect some level of breeding birds in any shelterbelt >0 ha. Thus, the nonzero y-intercept constant seems to be reasonable.

DISCUSSION

These data and earlier studies (Cassel and Wiehe 1980, Martin 1981) clearly reveal that the size of shelterbelts is the most important determinant of BSR. Habitat conditions, however, are necessary additions to the species-area relationship to most accurately predict BSR. The shelterbelts in this study were not highly isolated from other wooded tracts and isolation did not correlate with BSR. This conclusion is in agreement with Martin's (1981) studies of eastern South Dakota shelterbelts that had a mean distance between belts of 0.55 km. Forman and Baudry (1984) concluded that hedgerows serve as movement corridors across a landscape for many species and that wide tree-shrub hedgerows were more effective corridors than shrub hedgerows. Thus, degrees of shelterbelt isolation greater than we observed may affect either BSR or individual wildlife species. Whereas Johnson and Beck (1988) noted the importance of adjacent land types for the provision of food to shelterbelt wildlife, we found no relationship between adjacent cover and BSR.

Species richness does not provide indications of the value of shelterbelts to specific groups or individual wildlife species and does not provide information on the presence of nonnative species in the community. Only 3 species that are not native to North America were found in these shelterbelts (European starling [*Sturnus vulgaris*], house sparrow [*Passer domesticus*], and ring-necked pheasant [*Phasianus colchicus*]). The presence of forest-interior or area-sensitive breeding birds in large, mature shelterbelts in our study was of particular interest. Several of the older shelterbelts contained regenerating woody vegetation and were wide enough (up to 78 m) to begin to mimic conditions of eastern deciduous forest tracts. Hopkins (1984) noted that shelterbelts may be useful in mitigating losses of natural woodlands from activities such as surface mining. These results, however, should be viewed with caution. We did not gather information on breeding success, and nest predation and brown-headed cowbird (*Molothrus ater*) parasitism may be high in these island or edge habitats (Gates and Gysel 1978, Temple and Cary 1988). Although shelterbelts could benefit several forest-interior bird species, widespread planting of shelterbelts could harm certain prairie avifauna. Samson (1980) noted that the upland sandpiper (*Bartramia longicauda*), Henslow's sparrow (*Ammodramus henslowii*), and greater prairie-chicken (*Tympanuchus cupido*) require large expanses of prairie, and he suggested that recommendations to increase habitat heterogeneity (e.g., tree plantings) on open prairies should be viewed with caution. Land managers interested in managing shelterbelts for a group of species or a particular species may need to modify the model, as indicated by the habitat needs of the group or species. For general predictions of BSR, however, the revised HSI model should provide reliable estimates over much of the Great Plains region.

Acknowledgments.—We thank V. Brack, Jr., and P. S. Cook for assistance in the field, and P. S. Cook for assistance with data entry and analysis. B. S. Cade, A. H. Farmer, R. J. Johnson, W. C. McComb, D. F. Stauffer, R. H. Yahner, and 2 anonymous referees provided comments on the manuscript.

LITERATURE CITED

ALLEN, A. W., AND J. G. CORN. 1990. Relationships between live tree diameter and cavity abundance in a Missouri oak-hickory forest. North. J. Appl. For. 7:179–183.

BIONDINI, M. E., P. W. MIELKE, JR., AND E. F. REDENTE. 1988. Permutation techniques based on Euclidean analysis spaces: a new and powerful statistical method for ecological research. Coenoses 3:155–174.

BLAKE, J. G., AND J. R. KARR. 1984. Species composition of bird communities and the conservation benefits of large versus small forests. Biol. Conserv. 30:173–187.

CASSEL, J. F., AND J. M. WIEHE. 1980. Uses of shelterbelts by birds. Pages 78–87 *in* R. M. DeGraaf, tech. coord. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

COOK, J. G., AND L. L. IRWIN. 1985. Validation and modification of a habitat suitability model for pronghorns. Wildl. Soc. Bull. 13:440–448.

FORMAN, R. T. T., AND J. BAUDRY. 1984. Hedgerows and hedgerow networks in landscape ecology. Environ. Manage. 8:495–510.

GATES, J. E., AND L. W. GYSEL. 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology 59:871–883.

GRAUL, W. D., AND G. C. MILLER. 1984. Strengthening ecosystem management approaches. Wildl. Soc. Bull. 12:282–289.

HOPKINS, R. B. 1984. Avian species associated with prairie woodland types. Pages 27–35 *in* D. L. Noble and R. P. Winokur, eds. Proc. of symposium: wooded draws: characteristics and values for the

Northern Great Plains. Great Plains Agric. Counc. Publ. 111. S. D. School Mines and Technol., Rapid City.

Hutto, R. L., S. Reel, and P. B. Landres. 1987. A critical evaluation of the species approach to biological conservation. Endangered Species Update 4(12):1–4.

Johnson, R. J., and M. M. Beck. 1988. Influences of shelterbelts on wildlife management and biology. Agric. Ecosystems and Environ. 22/23:301–335.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594–598.

Martin, T. E. 1981. Species-area slopes and coefficients: a caution on their interpretation. Am. Nat. 118:823–837.

Morton, J. M., D. W. Howerter, and R. L. Kirkpatrick. 1989. Application of a habitat suitability index model for wintering black ducks. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 43:430–436.

Samson, F. B. 1980. Island biogeography and the conservation of prairie birds. Pages 293–299 *in* C. L. Kucera, ed. Proc. of the seventh North American prairie conference. Southwest Missouri State Univ., Springfield.

Schamberger, M., A. H. Farmer, and J. W. Terrell. 1982. Habitat suitability index models: introduction. U.S. Fish and Wildl. Serv. FWS/OBS-82/10. 2pp.

Schroeder, R. L. 1986. Habitat suitability index models: wildlife species richness in shelterbelts. U.S. Fish and Wildl. Serv. Biol. Rep. 82(10.128). 17pp.

———. 1987. Community models for wildlife impact assessment: a review of concepts and approaches. U.S. Fish and Wildl. Serv. Biol. Rep. 87(2). 41pp.

———. 1990. Tests of a habitat suitability model for black-capped chickadees. U.S. Fish and Wildl. Serv. Biol. Rep. 90(10). 8pp.

Small, M. F., and M. L. Hunter, Jr. 1989. Response of passerines to abrupt forest-river and forest-powerline edges in Maine. Wilson Bull. 101:77–83.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State Univ. Press, Ames. 593pp.

Temple, S. A. 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. Pages 301–304 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000, modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

———, and J. R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conserv. Biol. 2:340–347.

Yahner, R. H. 1983*a*. Seasonal dynamics, habitat relationships, and management of avifauna in farmstead shelterbelts. J. Wildl. Manage. 47:85–104.

———. 1983*b*. Small mammals in farmstead shelterbelts: habitat correlates of seasonal abundance and community structure. J. Wildl. Manage. 47:74–84.

———. 1983/1984. Avian use of nest boxes in Minnesota farmstead shelterbelts. J. Minn. Acad. Sci. 49:18–20.

Received 19 November 1991.
Accepted 18 February 1992.
Associate Editor: McComb.